BIO ACCENT

BAOJ Nutrition

Sibylle Kranz, et al., BAOJ Nutrition 2015 1: 1
1: 005

Research Artical

Food Sources of EPA and DHA in the Diets of American Children, NHANES 2003-2010

Sibylle Kranz[1*], Lyndsey R. Huss[2] and Jennifer Dobbs-Oates[3]

[1]*Senior Lecturer, Centre for Exercise, Nutrition, and Health Sciences, University of Bristol; formerly Associate Professor, Department of Nutrition Science, College of Health and Human Sciences, Purdue University, 700 W. State Street, West Lafayette, Indiana 47907-2059, USA*

[2]*Associate Nutritionist, Nestle Nutrition R&D Centers, Inc., Product Technology Center, 445 State Street, Fremont, Michigan 49413, USA; formerly Graduate Student, Department of Nutrition Science, College of Health and Human Sciences, Purdue University, 700 W. State Street, West Lafayette, Indiana 47907-2059, USA*

[3]*Clinical Assistant Professor, Department of Human Development and Family Studies, College of Health and Human Sciences, Purdue University, West Lafayette, Indiana 47907-2059, USA*

Abstract

Objective

Dietary eicosapentaenoicacid (EPA) and docosahexaenoic acid (DHA) are found in the highest concentrations in fish and seafood. As important nutrients for brain and eye development and function, their consumption levels are of public health interest, especially in children. This study was conducted toexamine children'sreported consumption of fish and shellfish as well as EPA and DHA intake.

Methods

Secondary analysis of dietary intake (24-hour recall) and Food Frequency Questionnaire (FFQ) data ascertaining habitual fish and seafood intake of 2-18 year olds (N=13,441) participating in the 2003-2004, 2005-2006, 2007-2008, and 2009-2010 National Health and Nutrition Examination Survey (NHANES). All analyses were survey design corrected and weighted (one-day dietary intake weight) and conducted for the total sample by age group (2-5, 6-11, 12-18 year olds); analysis was conducted for EPA and DHA combined.

Results

Less than 50% of the children consumed fish (49.0%) or shellfish (35.9%) and only 0.3% of the population consumed fish high in EPA and DHA. Children consumed, on average, less than 25% of the recommended amount of EPA and DHA. The foods that contributed the highest average of EPA and DHA to the diet were canned sardines, cooked salmon, and fried carp. The EPA and DHA-containing foods consumed by at least one child in the population with the highest EPA and DHA densities were sturgeon roe, baked/broiled mackerel, and sardines.

Conclusions

Results of this nationally representative study of 2-18 year olds show that children had suboptimal consumption of fish and shellfish, and EPA and DHA reported intakes were much below the recommended amounts. Further research is needed to examine the barriers to higher fish and shellfish consumption and to develop effective ways to increase children's dietary intake of EPA and DHA.

Introduction

The human body has the ability to elongate and desaturate alpha-linolenic acid (ALA) to the long chain omega-3 polyunsaturated fatty acids (n-3 PUFAs) eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [1-3]. However, Western diets are low in n-3 PUFAs, specifically ALA found in plant oils and EPA and DHA found in oily fish [4-6]. In the United States (US), the mean intake of n-3 PUFAs is 0.7% of total energy consumed [7], and intake in adults is very low with a median intake of EPA and DHA only contributing 0.05% of total dietary energy[7, 8]. Even individuals with low fish consumption have greater n-3 PUFA status than those individuals who do not consume any fish [9].

Western diets low in n-3 PUFAs and high in n-6 PUFAs contribute to poor brain development and function [4, 10]. It is uncertain if the rate of DHA synthesis in the human body is sufficient to support optimal brain and retinal development, and these PUFA swould ideally be provided in the diet [11]. DHA is the major n-3 PUFA esterified in glycerophospholipids through the action of acyl-CoA synthases and acyl-CoA:lysophospholipid acyltransferases [12], that forms the structural matrix of brain grey matter and retinal membranes [13, 14]. In addition, dietary intake of n-6 PUFAs play a role since n-6 PUFAs interact and compete with n-3 PUFAs in the fatty acid metabolic pathway [15-21].

***Corresponding author:** Sibylle Kranz, Senior Lecturer, Centre for Exercise, Nutrition, and Health Sciences, University of Bristol and formerly Associate Professor, Department of Nutrition Science, College of Health and Human Sciences, Purdue University, Indiana 47907-2059, USA, E-mail: sibylle.kranz@bristol.ac.uk

Sub Date: 5 November, 2015, **Acc Date:** 27 November, 2015, **Pub Date:** 28 November, 2015

Citation: Sibylle Kranz, Lyndsey R. Huss and Jennifer Dobbs-Oates (2015) Food Sources of EPA and DHA in the Diets of American Children, NHANES 2003-2010. BAOJ Nutrition 1: 005.

In the National Health and Nutrition Examination Survey (NHANES) 1999-2006, a food frequency questionnaire (FFQ) specifically designed to assess habitual fish consumption over a 30-day period was used. Tran et al. [22] found that the three most frequently consumed fish are tuna, salmon, and breaded fish. According to NHANES 2003-2008 dietary intake data, the food groups that contributed the greatest amount of DHA to the diets of American children were fish and shellfish (46.3%), poultry and poultry dishes (24.5%), eggs and egg dishes (19.6%), and pasta, rice and other grain dishes (2.2%) [23]. In children of all ages, racial groups, and ethnic groups (Non-Hispanic white or black and Mexican American) examined, the type of fish children most frequently consumed was white fish, followed by shellfish, and then oily fish. Young children in the US had the lowest reported EPA (6 mg/d) and DHA (20 mg/d) intake compared to children in Australia, Belgium, Canada, and China (mean ranges of 17-60 mg/d EPA and 23-96 mg/d DHA) [23, 24]. At the same time, US children had a greater mean intake of total n-6 PUFAs (8.6 g/d) compared to Australia, Canada, and China (6.20-7.60 g/d, 7.40-7.74 g/d, and 2.14-2.32 g/d, respectively) [23].

Multiple factors influence the n-3 PUFA content of the natural dietary sources of EPA and DHA. Even within each food type, variations in fatty acid content are based on factors, such as location, season, water temperature, age, sex, and diet[25]. Other natural sources of EPA and DHA are fatty animal tissue (with fatty fish being the best dietary source) [4], products of select marine sources (e.g. fish oil, krill oil, and algal oil) and other meats (e.g. poultry, eggs, beef, and pork) [26-28]. In addition to the natural food sources of n-3 PUFAs, numerous alternative sources are available in the US food market. Food production companies incorporate n-3 PUFAs into breads and pastas, milk, eggs, processed meats, salad dressings, margarine, mayonnaise, peanut butter, pizza, nutrition bars, cereal, yogurt and juices [27-31]. Incorporating n-3 PUFAs into commonly consumed foods (that do not naturally contain n-3 PUFAs) provides a cost-effective, sustainable venue to increase n-3 PUFA consumption, specifically EPA and DHA [32, 33]. Although the ALA, EPA, and/or DHA used in the fortification of foods is primarily from plant (ALA) or marine sources (EPA and DHA), the bioavailability and usefulness of these forms is currently understudied.

The 2010 Dietary Guidelines for Americans recommend that Americans consume seafood at least twice a week with "an intake of 8 or more ounces per week (less for young children)" that will provide a mean of 250 mg per day of EPA and DHA [34]. Furthermore, the Joint Food and Agriculture Organization (FAO) and World Health Organization (WHO) Expert Consultation on Fats and Fatty Acids in Human Nutrition provided recommendations for adequate intake levels of EPA and DHA for children and adults [35]. Although national and international public health organizations, professional organizations, and expert committees have made dietary recommendations for fish consumption or EPA and DHA intake [8, 36-38], to date, the Institute of Medicine has not established dietary reference intakes (DRIs) for EPA and DHA [39]. To develop effective public health nutrition policy, more specific EPA and DHA target intake levels (i.e. DRIs for EPA and DHA) must be established. There is a critical need for public health guidance on EPA and DHA intakes because substantial evidence indicates that these dietary fatty acids have many health benefits

Table 1: Population characteristics of children 2-18 year old with diet records, NHANES 2003-2010[1]

	2-18 year olds (n=13441)[2]	2-5 year olds (n=3380)[3]	6-11 year olds (n=4185)[4]	12-18 year olds (n=5876)[5]
	%			
Male	50.7	51.8	50.4	50.4
Ethnicity				
Mexican American	13.4	15.6	13.9	11.8
Non-Hispanic White	60.2	56.0	59.4	63.0
Non-Hispanic Black	14.4	14.2	14.5	14.4
Other Race	12.1	14.2	12.2	10.8
Income				
<1.30 PIR	32.0	36.8	32.1	29.2
1.30-1.84 PIR	11.1	12.0	12.1	9.8
1.85-3.49 PIR	25.5	25.1	24.8	26.2
3.50-5.00 PIR	31.4	26.1	31.0	34.7

[1]Data are presented as percentages
[2]Family PIR frequency missing=793
[3]Family PIR frequency missing = 206
[4]Family PIR frequency missing = 220
[5]Family PIR frequency missing = 367

[39] and play important roles in heart health [40], brain [11, 41-47] and eye development [48-51].

The overall goal of this project was to describe the reported consumption levels and food sources of fish and shellfish as well as EPA and DHA reported intake in the diets of American children, thereby advancing public health policy.

Methods

Dietary intake and socio-economic data including sex, race/ethnicity, and poverty income ratio (PIR) (Table 1) from children (n=13,441) ages 2-18 years in the NHANES 2003-2010 were extracted. PIR is the ratio of family income to the appropriate poverty threshold [52]. Ratios below 1.00 indicate that the family income is below the poverty threshold whereas a ratio of 1.00 or greater indicates income above the poverty threshold. Households with a PIR <1.3 are eligible for the United States Department of Agriculture (USDA) Supplemental Nutrition Assistance Program (SNAP); households with a PIR ≤1.85 PIR are eligible for participation in the USDA Women, Infants, and Children (WIC) Program; households with a PIR of 1.86-3.49 are defined as medium income; households with a PIR of 3.50-5.00 are defined as high income with all values >5.00 truncated to five [53].NHANES data are publicly available, de-identified data, thus, this study was "exempt" by the Institutional Review Board for Human Research.

Nutritional Variables

To code the nutrient and food-level data intakes, the USDA's Food and Nutrient Database for Dietary Studies (FNDDS), 5.0 (2012) [54] was used. The USDA food coding system was used to group foods into foodgroups with shared characteristics, such as "fish and shellfish", "meat, poultry, and fish with non-meat items", or "frozen and shelf-stable plate meals, soups, and gravies". Dietary intake data was provided by 24-hour recalls, which were used to rank-order (highest to lowest) the foods reportedly consumed by 2-18 year old children by EPA and DHA density (mg/g of food) and to calculate average EPA and DHA intake amounts. The nutrients EPA and DHA were analyzed as combined variable (EPA+DHA). Since the goal of this study was to examine the nutrients critical for brain and eye development, EPA and DHA content of food and their consumption levels were combined to account for the bio-conversion from EPA to DHA in the human body. Consumption of EPA and DHA was examined to determine tertiles of the total diet EPA and DHA density (mg/100g of food consumed) to identify and describe three levels of EPA and DHA consumers. Food-level data was analyzed using three approaches: a) the density of EPA and DHA in the foods (mg/100g of food), b) mean intake of EPA and DHA from foods (mg/d and number of children reportedly eating the food), and c) food list of all foods containing at least some EPA and DHA (more than zero mg/100g of food) and the number of children eating the food. To assess the effect of fish and shellfish intake on EPA and DHA intake, the responses to the FFQ assessing habitual fish intake were used to discern those children who ate fish or shellfish in the past 30 days from those who were classified as "not fish or shellfish consumers".

Statistical Analysis

All analyses were corrected for survey design and weighted (using the standard one-day dietary weight) to maintain the nationally representative character of the data and conducted in SAS V9.3 (SAS Institute Inc., Cary, NC, USA). Proc Survey Freq in SAS was used to estimate the percentage of the population in each race/ethnic, PIR, and sex category and to estimate the proportion of children who ate fish or shellfish in the past 30 days (FFQ responses). To determine the foods with the highest EPA and DHA density, all reported food items were identified and rank-ordered descending order of EPA and DHA density (mg/100g of food). Total EPA and DHA intake was calculated by multiplying EPA and DHA density with amount of food eaten. The mean intake of each food item and each food group was calculated. Also, the number of children reporting each food item with EPA or DHA was ascertained. Consumption data are reported as mean ± standard error or as percentages.

Results

This study included a nationally representative sample of children whose sociodemographic characteristics reflect the demographic profiles of the American population with approximately 50.7% of the children male, 60.2 non %Hispanic white, and 32.0% from a household with a PIR < 1.30 (Table 1). The foods with the highest EPA and DHA density (mg/100g food) reportedly consumed by children ages 2-18 years old are reported in (Table2) and separated by age group (Supplemental Table 1). To directly compare the EPA and DHA density of food items consumed by age group, refer to Figures 1-4. Analysis showed that 19 of the top 20 foods with the highest EPA and DHA density were from the fish and shellfish food group, with the exception of cooked brains (consumed by one child); the greatest densities were found in sturgeon roe, baked/broiled mackerel, and skinless, boneless, water-packed sardines. Analysis of the top 20 food source of the highest contributors to dietary EPA and DHA in 2-18 year olds (Table 3) showed that all of those foods were fish or shellfish and were eaten by only small numbers of children, i.e. only three children consumed sardines or cooked salmon, one child ate fried carp, but 16 children ate battered and fried fish (fish not specified) and 34 children consumed baked or broiled salmon. The data are presented by age group (2-5, 6-11, and 12-18 year olds in Supplemental Table 2).

Overall, the mean EPA and DHA intake was 48 ± 0.002 mg/d. This value varied by age group with 37 ± 0.002 mg/d, 45 ± 0.003 mg/d, and 58 ± 0.003 mg/d of EPA and DHA in 2-5, 6-11, and 12-18 years old, respectively [Figure 5]. However, when children not consuming dietary EPA and DHA were excluded from the calculation, the mean daily intake of EPA and DHA increased to 59 ± 0.002 mg/d for 2-18 year old children, 44 ± 0.003 mg/d for 2-5 year old children, 53 ± 0.004 mg/d for 6-11 year old children, and 72 ± 0.004 mg/d for 12-18 year old children. Furthermore, when only those children who were identified as "fish and shellfish eaters" using the FFQ were included in the calculations, the mean EPA and DHA intake further increased to an average of 64 ± 0.003 mg/d for 2-18 year olds (62.0% consumed seafood) and 49 ± 0.004 mg/d for 2-5 year olds (63.4% consumed seafood), 61 ± 0.006 mg/d

Supplemental Table 1: The food items with highest EPA + DHA density consumed by children ages 2-5, 6-11, and 12-18 years old[1]

	2-5 years old		6-11 years old		12-18 years old	
Food Rank	Main food description	EPA and DHA density (mg/100g food)	Main food description	EPA and DHA density (mg/100g food)	Main food description	EPA and DHA density (mg/100g food)
1	Sardines, skinless, boneless, water-packed	2150	Squid, dried	1848	Roe, sturgeon	6548
2	Herring, pickled	1389	Salmon, canned	1587	Mackerel, baked/broiled	2351
3	Salmon, steamed/poached	1256	Salmon, baked/broiled	1079	Sardines, skinless, bone-less, water-packed	2149
4	Salmon, baked/broiled	1088	Salmon, cooked, cooking method NS	1052	Herring, baked/broiled	2024
5	Trout, baked/broiled	1009	Salmon, floured/breaded, fried	987	Mackerel, floured/bread-ed, fried	1607
6	Sardines, cooked	982	Sardines, canned in oil	983	Salmon, canned	1587
7	Mussels, steamed/poached	875	Mussels, steamed/ poached	875	Sardines with tomato-based sauce (mixture)	1396
8	Salmon, battered, fried	863	Salmon, battered, fried	863	Trout, baked/broiled	1083
9	Sea bass, steamed/poached	741	Trout, breaded/battered, baked	765	Salmon, baked/broiled	1077
10	Sea bass, baked/broiled	731	Sea bass, baked/broiled	742	Salmon, cooking method NS	1056
11	Trout, floured/breaded, fried	717	Pompano, baked/broiled	681	Sardines, cooked	983
12	Pompano, baked/broiled	715	Trout, floured/breaded, fried	665	Sardines, canned in oil	981
13	Swordfish, floured/breaded, fried	687	Trout, battered, fried	650	Salmon, steamed/ poached	948
14	Trout, battered, fried	651	Salmon cake or patty	632	Mussels, steamed/ poached	875
15	Salmon cake or patty	634	Fish, type NS, baked/ broiled	608	Brains, cooked	847
16	Sea bass floured/breaded, fried	564	Sea bass, floured/bread-ed, fried	585	Salmon, floured/breaded, fried	834
17	Fish, type NS, baked/broiled	515	Fish, cooked, type and cooking method NS	584	Sea bass, baked/broiled	723
18	Fish, type NS, smoked	512	Squid, baked, broiled	583	Pompano, baked/broiled	702
19	Shrimp, cooked, cooking method NS	508	Oysters, raw	560	Trout, floured/breaded, fried	695
20	Fish, cooked, type and cooking method NS	505	Oysters, floured/breaded, fried	534	Oysters, steamed	695

[1]Data are presented as mg/100g of food item

for 6-11 year olds (63.7% consumed seafood), and 77 ± 0.004 mg/d for 12-18 year olds (59.8% consumed seafood).

When EPA and DHA from all sources were considered, the tertiles of total dietary EPA and DHA density in the foods were <5 mg/100g in the lowest tertile, 5-21 mg/100g in the medium tertile, and >21 mg/100g in the highest consumption tertile.The USDA food groups contributing most to the daily EPA and DHA intake (mg/d) were calculated and reported in (Table 4), it at least one of the food items in each food group was reportedly consumed and if at least 15 children reported eating food items from this food group. Fish and shellfish contributed the most EPA and DHA, followed by “meat, poultry, and fish with non-meat items”, and “frozen and shelf-stable plate meals, soups, and gravies”. Results

Table 2: The food items with the highest EPA and DHA density(mg of EPA and DHA per 100 g food) consumed by children ages 2-18 years old[1]

Food Ranking	Main Food Description	EPA and DHA density (mg/100g food)
1	Roe, sturgeon	6548
2	Mackerel, baked/broiled	2351
3	Sardines, skinless, boneless, water-packed	2149
4	Herring, baked/broiled	2024
5	Squid, dried	1848
6	Mackerel, floured/breaded, fried	1607
7	Salmon, canned	1587
8	Sardines with tomato-based sauce (mixture)	1396
9	Herring, pickled	1389
10	Salmon, baked/broiled	1079
11	Salmon, cooked, cooking method NS	1056
12	Salmon, steamed/poached	1050
13	Trout, baked/broiled	1009
14	Sardines, canned in oil	983
15	Sardines, cooked	982
16	Mussels, steamed/poached	875
17	Brains, cooked	847
18	Salmon, floured/breaded, fried	834
19	Trout, breaded/battered, baked	765
20	Sea bass, steamed/poached	741

[1]Data are presented as mg of EPA and DHA per 100g of edible food

Figure 1 Foods with highest EPA+DHA density reportedly consumed by 2-18 year olds (N=13,441)

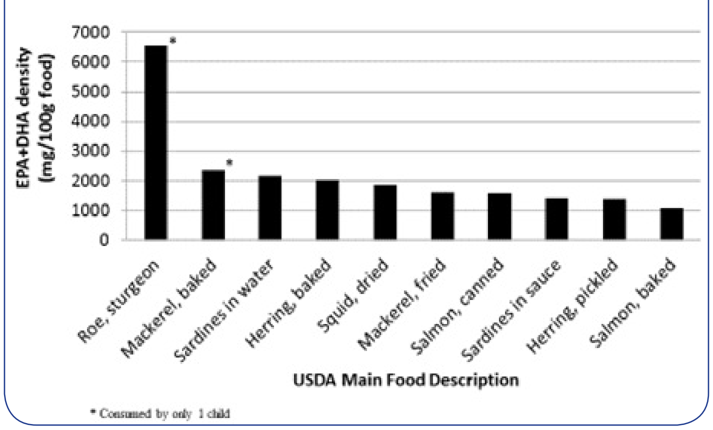
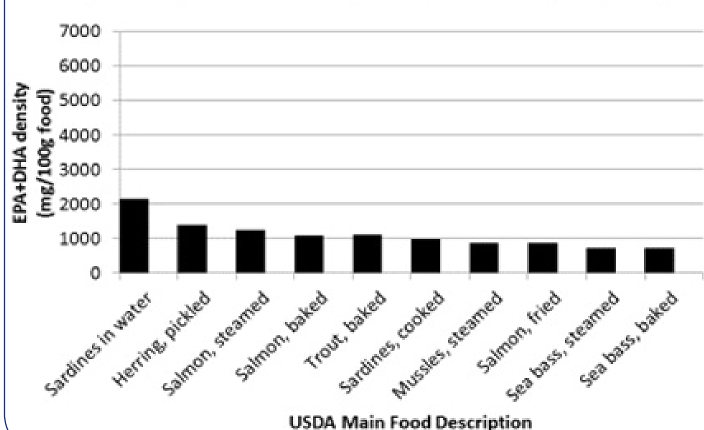


Figure 2 Foods with highest EPA+DHA density reportedly consumed by 2-5 year olds (N=3,380)



also showed that the majority of 2-18 year old children (82.5%) had at least some dietary EPA and DHA intake (any intake greater than zero). Examination of the EPA and DHA densities of all foods consumed showed that the proportion of children reportedly eating fish or shellfish in the previous 30 days was calculated using the data from the supplementary FFQ on habitual fish and seafood intake. Only 35.9% of participants reportedly consumed shellfish and 49% reportedly consumed fish. Since child's age may have an effect on fish and seafood intake, the sample was divided by age group and results showed that 31.6% and 54.5%, 35.9% and 52.3%, as well as 38.6% and 42.8%of2-5, 6-11, and 12-18 year old children consumed shellfish and fish, respectively, in the past 30 days.

Considering EPA and DHA intake from all sources, the food items that provided the most EPA and DHA were "skinless, boneless,

Figure 3 Foods with highest EPA+DHA density reportedly consumed by 6-11 year olds (N=4,185)

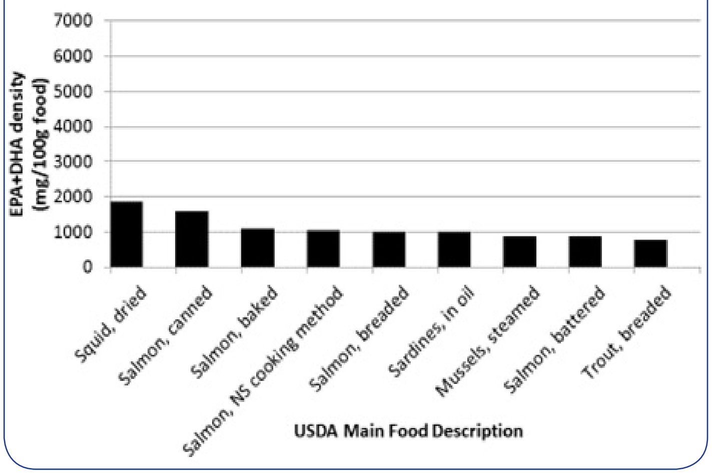


Figure 4 Foods with highest EPA+DHA density reportedly consumed by 12-18 year olds (N=5,876)

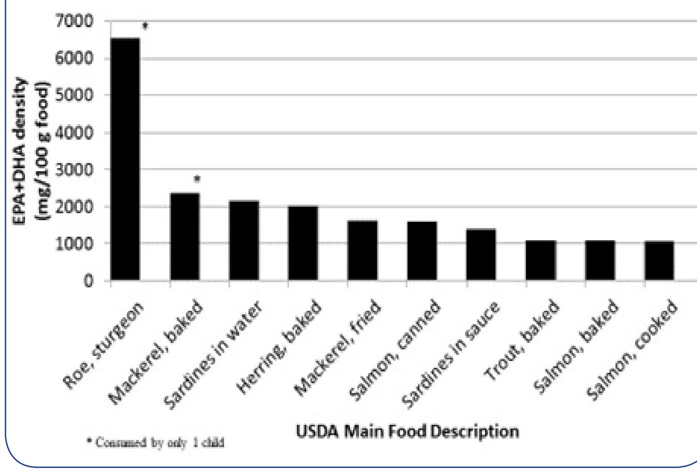


Table 3: Highest contributors[1] to mean EPA and DHA dietary intake of children ages 2-18 years old and the number of children reported eating the food item

Food Ranking	Main Food Description	Mean EPA and DHA intakes (mg/d)	Number of children reporting food
1	Sardines, skinless, boneless, water-packed	2093	3
2	Salmon, cooked, NS as to cooking method	1724	3
3	Carp, floured or breaded, fried	1538	1
4	Fish, NS as to type, battered, fried	1224	16
5	Salmon, steamed or poached	1148	3
6	Salmon, baked or broiled	1124	34
7	Trout, breaded or battered, baked	1050	1
8	Shrimp creole, with rice	987	4
9	Salmon, floured or breaded, fried	935	2
10	Sardines with tomato-based sauce (mixture)	932	1
11	Haddock, floured or breaded, fried	903	1
12	Sea bass, baked or broiled	895	3
13	Oysters, canned	877	1
14	Mackerel, floured or breaded, fried	868	1
15	Sea bass, floured or breaded, fried	858	3
16	Mussels, steamed/poached	804	3
17	Squid, dried	776	1
18	Swordfish, floured/breaded, fried	731	2
19	Herring, pickled	690	3
20	Scallops, baked/broiled	675	1

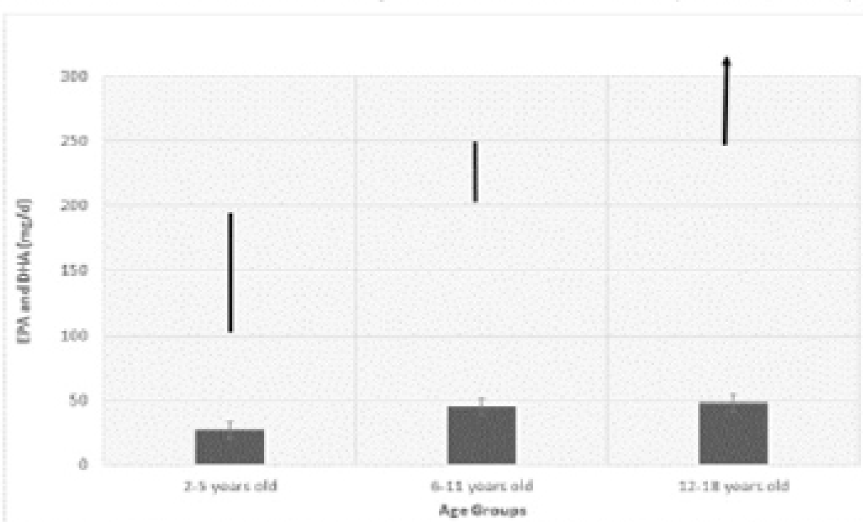
[1]Contribution of EPA and DHA calculated as EPA and DHA content of the food multiplied by the amount of the food item reportedly consumed

Supplemental Table 2: Highest contributors[1] to mean EPA and DHA dietary intake of children by age-group and the number of children reported eating the food item[1]

2-5 years old			6-11 years old			12-18 years old		
Food Group	**EPA and DHA intake (mg/day)**	**Children reporting food**	**Food Group**	**EPA and DHA intake (mg/day)**	**Children reporting food**	**Food Group**	**EPA and DHA intake (mg/day)**	**Children reporting food**
Fish and shellfish	282	206	Fish and shell-fish	309	242	Fish and shellfish	491	337
Frozen & shelf-stable plate meals, soups & gravies	51	117	Meat, poultry, fish with non-meat items	48	676	Meat, poultry, fish with nonmeat items	67	1040
Egg mixtures	33	521	Egg mixtures	41	508	Frozen & shelf-stable plate meals, soups & gravies	59	86
Meat, poultry, fish with nonmeat items	33	532	Frozen & shelf-stable plate meals, soups & gravies	32	101	Egg mixtures	44	582
Eggs	24	190	Eggs	30	209	Poultry	40	1327
Poultry	20	822	Poultry	28	1007	Eggs	34	226
Grain mixtures, frozen plate meals, soups	11	484	Grain mixtures, frozen plate meals, soups	14	767	Grain mixtures, frozen plate meals, soups	19	917
Other vegetables	11	15	Pancakes, waffles, French toast, other grain products	8	473	Pancakes, waffles, French toast, other grain products	11	368
Pancakes, waffles, French toast, other grain products	6	293	White potatoes and Puerto Rican starchy vegetables	5	106	Organ meats, sausages and lunchmeats, and meat spreads	7	459

[1]Data are presented as mean intake of EPA and DHA intake in mg/d, rank-ordered by EPA and DHA intake with n = number of children reportedly consuming food

Figure 5 Weighted average EPA and DHA intake compared to the intake recommendation* in 2-18 year old children (N=13,441)



* WHO/FAO intake recommendation for EPA and DHA (100-200 mg/d in 2-5; 200-250 mg/d in 6-11, and 250-2000 mg/d in 12-18 year olds

Table 4: The USDA food groups contributing most dietary EPA and DHA to the diets of children ages 2-18 years old, NHANES 2003-2010[1]

Food Group	EPA+DHA intake (mg/d)		Number of children reporting food[2]
	Mean	SE	
Fish and shellfish	373	0.026	785
Meat, poultry, fish with nonmeat items	53	0.004	2248
Frozen & shelf-stable plate meals, soups & gravies	47	0.006	304
Egg mixtures	40	0.001	1611
Poultry	32	0.001	3156
Eggs	30	0.001	625
Grain mixtures, frozen plate meals, soups	16	0.001	2168
Pancakes, waffles, French toast, other grain products	8	<0.001	1134
Organ meats, sausages and lunchmeats, and meat spreads	6	<0.001	1116
White potatoes and Puerto Rican starchy vegetables	6	<0.001	260
Other vegetables	5	<0.001	85
Cereals, not cooked or NS as to cooked	5	<0.001	1546
Quick breads	4	<0.001	329
Salad dressings	4	<0.001	63
Beef	4	<0.001	463
Cakes, cookies, pies, and pastries	4	<0.001	2199
Cheeses	3	<0.001	545
Milk desserts, sauces, gravies	3	<0.001	1723
Pork	3	<0.001	78
Crackers and salty snacks from grain products	3	<0.001	598

[1]Data are presented as mean and SE of EPA and DHA intake (mg/d), rank-ordered by EPA and DHA amounts

[2]Number of children reportedly consuming at least one food item from the food group. Food groups with less than 15 children reportedly consuming at least one food item from the USDA food group are not shown.

water-packed sardines", "cooked salmon", and "floured/breaded fried carp". When examining all foods that were reportedly consumed by the children and that contained any EPA and DHA, non-fish items emerged as most consumed contributors to dietary EPA and DHA intake, i.e. ice cream, salty snacks, and eggs ranked at the top (Table 5). After expanding the list and examining the 50 foods that contributed the most EPA and DHA to children's diets, tuna salad was the only fish/shellfish-based food and ranked in the 38thplace. The tuna salad, commonly assumed to be a regularly consumed food, was eaten by only 127 children and provided on average 167.6 mg of EPA and DHA per day.

Discussion

This study provides new data on fish and shellfish as well as EPA and DHA consumption of American children ages 2-18 years old. Results showed that the majority of children had at least some dietary EPA and DHA intake. Food sources of EPA and DHA included nutrient dense foods, such as fish and shellfish, but also high fat, sweet desserts and salty snacks (i.e. ice cream and chips). On average, only 35.9% of the children consumed shellfish and 49% consumed fish;with increasing age, more children ate shellfish but less children had fish.

The foods with the greatest EPA and DHA density (mg/100g food) that were consumed by any 2-18 year old child were roe, mackerel, and sardines and other fish and shell fish, however these EPA and DHA-rich foods were not commonly consumed by the majority of children. This might be due to barriers such as lack of food access (i.e. ability to obtain or retrieve food from local stores), lack of availability (i.e. the quantity and quality of food that is provided by caretakers and caretakers' knowledge and ability to prepare fish) [55], and the social context in which the food is encountered such as role models not eating seafood and/or habitual consumption i.e. the children are not used to the odor or flavor of these food sources [56].

The weighted mean EPA and DHA in takes per day were 37 mg, 45 mg, and 58 mg for 2-5, 6-11, and 12-18 year olds, respectively – much below the intake recommendations by the Joint FAO and WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition Adequate Intake levels of 100-150 mg for 2-4 year olds, 150-200 mg for 4-6 year olds, 200-250 mg for 6-10 year olds, and 250-2000 mg for people 10 years and older [35] as Figure 5 shows.

Table 5: The food items containing any EPA and DHA, the number of 2-18 year old children reportedly consuming the food, and the mean contribution of the food items to children daily EPA and DHA intake[1]

Food Ranking	Main Food Description	Number of children reporting food	EPA and DHA consumed (mg/d)	
			Mean	SE
1	Ice cream, regular, flavors other than chocolate	989	3.6	<0.001
2	Salty snacks, corn or cornmeal base, tortilla chips	581	2.4	<0.001
3	Egg omelet or scrambled egg, fat added in cooking	537	39.0	0.002
4	Chicken or turkey loaf, prepackaged or deli, luncheon meat	501	7.4	0.001
5	Pancakes, plain	409	1.2	<0.001
6	Waffle, plain	395	12.1	0.001
7	Chicken patty, fillet, or tenders, breaded, cooked	354	4.5	<0.001
8	Egg, whole, fried	353	31.8	0.001
9	Spaghetti with tomato sauce and meatballs, meat sauce, or meat sauce and meatballs	328	3.5	<0.001
10	Cheerios	325	6.0	<0.001
11	Froot Loops	297	1.7	<0.001
12	Chicken, drumstick, coated, baked or fried, prepared with skin, skin/coating eaten	281	35.0	0.002
13	Chicken, wing, coated, baked or fried, prepared with skin, skin/coating, eaten	275	45.6	0.003
14	Bread, white	240	1.1	<0.001
15	Egg omelet or scrambled egg, fat not added in cooking	234	42.0	0.002
16	Roll, sweet, cinnamon bun, frosted	229	2.3	<0.001
17	Chicken, NS as to part and cooking method, NS as to skin eaten	227	40.5	0.003
18	Cheese, processed, American or Cheddar type	226	3.9	<0.001
19	Corn dog (Frankfurter or hot dog with cornbread coating)	225	3.5	<0.001
20	Egg omelet or scrambled egg, NS as to fat added in cooking	210	40.7	0.003

[1]Data are presented as mean and SE of EPA and DHA intake in mg/d, rank-ordered by the number of children consuming the food

This finding is alarming since, especially in younger children, EPA and DHA are critical nutrients to promote healthy brain and eye development and function. Based on the food sources identified in this study, the dramatic under consumption of dietary EPA and DHA may be due to the low proportion of children consuming fish and shellfish, which were the most EPA- and DHA-dense foods consumed by the children. The proportion of children consuming these foods was 1: 34 children or < 0.3% of the sample population (N=13,441).

The majority of children were not consuming the foods highest in EPA and DHA and further analysis showed that consumption of foods contributing any EPA and DHA was too low to meet the intake recommendations, i.e. total daily contribution of ice cream was 3.6 mg (which was the single most consumed EPA and DHA-containing food) and that of egg omelet or scrambled egg was 39.0 mg (highest contribution to daily EPA and DHA intake but only consumed by 537 children). Tuna salad, commonly served in childcare centers and schools, ranked only thirty-eighth place and contributed small amounts of EPA and DHA to children's diets.

Not surprisingly, fish and shellfish was the food group contributing the largest amount of EPA and DHA to 2-18 year olds diets. However, as the analysis of consumption amounts and frequency showed, very few children consumed these foods (0.3% of the population). Thus, it appears that an important public health policy should be to increase the proportion of the pediatric population consuming these foods. Previous research to examine acceptability of fatty fish meals in 2-5 year old children has shown that young children accepted oily fish when it was incorporated into familiar foods such as macaroni-and-cheese and wraps [57], thereby significantly increasing EPA and DHA intakes.

The present study had several strengths and limitations. The strengths include, but are not limited to, the large sample size and representation of the US population, the use of validated instruments to estimate EPA and DHA intake, and the pooling of four NHANES survey years (2003-2004, 2005-2006, 2007-2008, and 2009-2010). One limitation of the analysis was that the dietary intake estimates were based on one single 24-hour dietary recall. The 24-hour dietary recall is one of the most commonly used dietary intake estimation methods, especially in large nutrition surveys and has been validated for adults and children in the US

[58-61] because 24-hour dietary recalls provide comparable data to other methods and with reduced effort and cost [62]. However, one day of intake does not provide a good estimate of usual intake especially of rarely consumed foods such as fish and shellfish, and children's diets might not be accurately captured in a single 24-hour recall. However, some of this variation was accounted for by the use of the FFQ assessing fish and seafood consumption over a 30-day period.

Conclusions

This study provides important information on the food sources and the dietary intake of EPA and DHA, which are important essential fatty acids for brain and eye development and function, in 2-18 year old American children. Results indicate that fish and shellfish provide the highest EPA and DHA density, but are not commonly consumed foods. Accordingly, estimated average EPA and DHA intake amounts were dramatically below the current intake recommendation levels. Higher consumption levels of EPA and DHA would be beneficial and should be recommended, however, as data from this study show, fish and shellfish are not well accepted in children ages 2-18 years old. Future research should investigate the barriers (e.g. fish consumption advice, availability of and accessibility to oily fish, preparation ability by parents, parental eating habits, and cost) to elucidate why so many children are not consuming fish and shellfish. In addition, healthy alternative dietary sources of EPA and DHA may have to be explored.

References

1. Cinti DL, Cook L, Nagi MN, Suneja SK (1992) The fatty acid chain elongation system of mammalian endoplasmic reticulum. Prog Lipid Res 31: 1-51.
2. Seubert W, Podack ER (1973) Mechanisms and physiological roles of fatty acid chain elongation in microsomes and mitochondria. Mol Cell Biochem 11: 29-40.
3. Cook HW, McMaster CR (2002) Fatty acid desaturation and chain elongation in eukaryotes. Biochemistry of Lipids, Lipoproteins and Membranes, 4th ed., pp. 181-204 [D.E. Vance and J.E. Vance, editors]. Elsevier Science B.V.
4. Innis SM (2008) Dietary omega 3 fatty acids and the developing brain. Brain Res 1237: 35-43.
5. Simopoulos AP (2002) The importance of the ratio of omega-6/ omega-3 essential fatty acids. Biomed Pharmacother 56: 365-379.
6. Simopoulos AP (1991) Omega-3 fatty acids in health and disease and in growth and development. Am J Clin Nutr 54: 438-463.
7. Kris-Etherton PM Taylor DS, Fishell V, Yu-Poth S, Huth P, Moriarty K et al. (2000) Polyunsaturated fatty acids in the food chain in the United States. Am J Clin Nutr 71:179S-188S.
8. Institute of Medicine (2005) Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. Washington, DC: Institute of Medicine, Food and Nutritoin Board, National Academic Press; available at
9. Sichert-Hellert W, Wicher M, Kersting M (2009) Age and time trends in fish consumption pattern of children and adolescents, and consequences for the intake of long-chain n-3 polyunsaturated fatty acids. Eur J Clin Nutr 63:1071-1075.
10. Rosales FJ, Reznick JS, Zeisel SH (2009) Understanding the role of nutrition in the brain & behavioral development of toddlers and preschool children: identifying and overcoming methodoligcal barriers. Nutr Neurosci 12:190-202.
11. Innis SM (2003) Perinatal biochemistry and physiology of long-chain polyunsaturated fatty acids. J Pediatr 143: S1-S8.
12. Farooqui AA, Horrocks LA, Farooqui T (2000) Deacylation and reacylation of neural membrane glycerophospholipids. J Mol Neurosci 14: 123-135.
13. Sastry PS (1985) Lipids of nervous tissue: composition and metabolism. Prog Lipid Res 24: 69-176.
14. Giusto NM, Salvador GA, Castagnet PI, Pasquaré SJ, Ilincheta de Boschero MG (2002) Age-associated changes in central nervous system glycerolipid composition and metabolism. Neurochem Res 27:1513-1523.
15. Bourre JM, Piciotti M, Dumont O, Pascal G, Durand G (1990) Dietary linoleic acid and polyunsaturated fatty acids in rat brain and other organs. Minimal requirements of linoleic acid. Lipids 25: 465-472.
16. Bourre JM, Francois M, Youyou A, Dumont O, Piciotti M, et al. (1989) The effects of dietary alpha-linolenic acid on the composition of nerve membranes, enzymatic activity, amplitude of electrophysiological parameters, resistance to poisons and performance of learning tasks in rats. J Nutr 119: 1880-1892.
17. Galli C, Agradi E, Petroni A, Tremoli E (1981) Differential effects of dietary fatty acids on the accumulation of arachidonic acid and its metabolic conversion through the cyclooxygenase and lipoxygenase in platelets and vascular tissue. Lipids 16: 165-172.
18. Hrboticky N, MacKinnon MJ, Innis SM (1990) Effect of a vegetable oil formula rich in linoleic acid on tissue fatty acid accretion in the brain, liver, plasma, and erythrocytes of infant piglets. Am J Clin Nutr 51: 173-182.
19. Hrboticky N, MacKinnon MJ, Innis SM (1991) Retina fatty acid composition of piglets fed from birth with a linoleic acid-rich vegetable-oil formula for infants. Am J Clin Nutr 53: 483-490.
20. Innis SM (1991) Essential fatty acids in growth and development. Prog Lipid Res30, 39-103.
21. Arbuckle LD, MacKinnon MJ, Innis SM (1994) Formula 18:2(n-6) and 18:3(n-3) content and ratio influence long-chain polyunsaturated fatty acids in the developing piglet liver and central nervous system. J Nutr 124: 289-298.
22. Tran NL, Barraj LM, Bi X, Schuda LC, Moya J (2013) Estimated long-term fish and shellfish intake--national health and nutrition examination survey. J Expo Sci Environ Epidemiol 23: 128-136.
23. Keim SA, Branum AM (2013) Dietary intake of polyunsaturated fatty acids and fish among US children 12-60 months of age. Matern Child Nutr doi:10.1111/mcn.12077
24. Rahmawaty S, Charlton K, Lyons-Wall P, Meyer BJ (2013) Dietary intake and food sources of EPA, DPA and DHA in Australian children. Lipids 48: 869-877.
25. Harris K, Fleming J, Kris-Etherton P (2011) Challenges in estimating omega-3 fatty acid content of seafood from US nutrient databases: A salmon case study. Journal of Food Composition and Analysis 24: 1168-1173.

26. Ganuza E, Benitez-Santana T, Atalah E, Vega-Orellana O, Ganga R, et al. (2008) Crypthecodinium cohnii and Schizochytrium sp. as potential substitutes to fisheries-derived oils from seabream (Sparus aurata) microdiets. Aquaculture 277:109-116.
27. Tur JA, Bibiloni MM, Sureda A, Pons A (2012) Dietary sources of omega 3 fatty acids: public health risks and benefits. Br J Nutr 107: S23-S52.
28. Whelan J, Rust C (2006) Innovative dietary sources of n-3 fatty acids. Annu Rev Nutr 26: 75-103.
29. Whelan J, Jahns L, Kavanagh K (2009) Docosahexaenoic acid: measurements in food and dietary exposure. Prostaglandins Leukot Essent Fatty Acids 81: 133-136.
30. Sioen I, Vyncke K, De Maeyer M, Gerichhausen M, De Henauw S (2013) Dietary intake and food sources of total and individual polyunsaturated fatty acids in the belgian population over 15 years old. Lipids 48: 729-738.
31. Smuts CM, Borod E, Peeples JM, Carlson SE (2003) High-DHA eggs: feasibility as a means to enhance circulating DHA in mother and infant. Lipids 38: 407-414.
32. Ke 0101 xnnedy ET, Luo H, Ausman LM (2012) Cost implications of alternative sources of (n-3) fatty acid consumption in the United States. J Nutr 142: 605S-609S.
33. Nichols PD, Petrie J, Singh S (2010) Long-chain omega-3 oils-an update on sustainable sources. Nutrients 2: 572-585.
34. U.S. Department of Agriculture and U.S. Department of Health and Human Services. (2010) Dietary Guidelines for Americans, 2010 7th Edition, Washington, DC: U.S. Government Printing Office.
35. World Health Organization-Food and Agriculture Organization. (2008) Interim summary of conclusions and dietary recommendations on total fat & fatty acids. From the Joint FAO/WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition, November 10-14: 2008. Geneva, Switzerland: WHO.
36. Gebauer SK, Psota TL, Harris WS, Kris-Etherton PM (2006) n-3 fatty acid dietary recommendations and food sources to achieve essentiality and cardiovascular benefits. Am J Clin Nutr 83:1526S-1535S.
37. Smith KM, Sahyoun NR (2005) Fish consumption: recommendations versus advisories, can they be reconciled? Nutr Rev 63: 39-46.
38. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, et al. (2013) Update of the Healthy Eating Index: HEI-2010. J Acad Nutr Diet 113: 569-580.
39. Flock MR, Harris WS, Kris-Etherton PM (2013) Long-chain omega-3 fatty acids: time to establish a dietary reference intake. Nutr Rev 71: 692-707.
40. Mozaffarian D, Wu JH (2012) (n-3) Fatty Acids and Cardiovascular Health: Are Effects of EPA and DHA Shared or Complementary? J Nutr 142: 614S-625S.
41. Cao D, Kevala K, Kim J, Moon HS, Jun SB, et al. (2009) Docosahexaenoic acid promotes hippocampal neuronal development and synaptic function. J Neurochem 111: 510-521.
42. Innis SM (2007) Dietary (n-3) fatty acids and brain development. J Nutr 137: 855-859.
43. Chalon S, Vancassel S, Zimmer L, Guilloteau D, Durand G (2001) Polyunsaturated fatty acids and cerebral function: focus on monoaminergic neurotransmission. Lipids 36: 937-944.
44. Greenberg JA, Bell SJ, Ausdal WV (2008) Omega-3 Fatty Acid supplementation during pregnancy. Rev Obstet Gynecol 1: 162-169.
45. Boucher O, Burden MJ, Muckle G, Saint-Amour D, Ayotte P ,et al. (2011) Neurophysiologic and neurobehavioral evidence of beneficial effects of prenatal omega-3 fatty acid intake on memory function at school age. Am J Clin Nutr 93: 1025-1037.
46. Richardson AJ, Burton JR, Sewell RP, Spreckelsen TF, Montgomery P, et al. (2012) Docosahexaenoic acid for reading, cognition and behavior in children aged 7-9 years: a randomized, controlled trial (the DOLAB Study). PLoS One7, e43909. doi:10.1371/journal.pone.0043909.
47. de Groot RH, Ouwehand C, Jolles J (2012) Eating the right amount of fish: inverted U-shape association between fish consumption and cognitive performance and academic achievement in Dutch adolescents. Prostaglandins Leukot Essent Fatty Acids 86:113-117.
48. Jeffrey BG, Weisinger HS, Neuringer M, Mitchell DC (2001) The role of docosahexaenoic acid in retinal function. Lipids 36: 859-871.
49. SanGiovanni JP, Chew EY (2005) The role of omega-3 long-chain polyunsaturated fatty acids in health and disease of the retina. Prog Retin Eye Res 24:87-138.
50. Birch EE, Garfield S, Castaneda Y, Hughbanks-Wheaton D, Uauy R, Hoffman D, et al. (2007) Visual acuity and cognitive outcomes at 4 years of age in a double-blind, randomized trial of long-chain polyunsaturated fatty acid-supplemented infant formula. Early Hum Dev 83: 279-284.
51. Jacques C, Levy E, Muckle G, Jacobson SW, Bastien C, Dewailly E, Ayotte P, Jacobson JL, Saint-Amour D,et.al (2011) Long-term effects of prenatal omega-3 fatty acid intake on visual function in school-age children. J Pediatr 158:73-80.e1. doi:10.1016/j.jpeds.2010.06.056.
52. U.S. Census Bureau, Population Devision, Fertility & Familty Statistics Branch. (2004). Current population survey: Definitions and explanations .
53. U.S. Department of Agriculture (2014) The Food and Nutrition Service Handbook 901. In: Food and Nutrition Service, editor.
54. Ahuja JKA, Montville JB, Omolewa-Tomobi G, Heendeniya KY, Martin CL et al. (2012) USDA Food and Nutrient Database for Dietary Studies, 5.0. U.S. Department of Agriculture, Agricultural Research Service, Food Surveys Research Group, Beltsville, MD.
55. Vallianatos M, Azuma AM, Gilliland S, Robert Gottlieb (2010) Food access, availability, and affordability in 3 Los Angeles communities, project CAFÉ, 2004-2006. Prev Chronic Dis 7:A27.
56. Addessi E, Galloway AT, Visalberghi E, Birch LL (2005) Specific social influences on the acceptance of novel foods in 2-5-year-old children. Appetite 45: 264-271.
57. Huss LR, McCabe SD, Dobbs-Oates J, Carl Behnke3, Charles Santerre2 and Sibylle Kranz2, John Burgess2, et al. (2013) Development of child-friendly fish dishes to increase young children's acceptance and consumption of fish. Food and Nutrition Sciences 4:78-87.
58. Posner BM, Borman CL, Morgan JL, Borden WS, Ohls JC, et al. (1982) The validity of a telephone-administered 24-hour dietary recall methodology. Am J Clin Nutr 36:546-553.
59. Galasso R, Panico S, Celentano E, Del Pezzo M (1994) Relative validity of multiple telephone versus face-to-face 24-hour dietary recalls. Ann Epidemio l4:332-336.

60. Casey PH, Goolsby SL, Lensing SY, Perloff BP, Bogle ML (1999) The use of telephone interview methodology to obtain 24-hour dietary recalls. J Am Diet Assoc 99:1406-1411.

61. Yanek LR, Moy TF, Raqueno JV, Becker DM (2000) Comparison of the effectiveness of a telephone 24-hour dietary recall method vs an in-person method among urban African-American women. J Am Diet Assoc 100:1172-1177.

62. Morgan KJ, Johnson SR, Rizek RL, Reese R, Stampley GL, et al. (1987) Collection of food intake data: an evaluation of methods. J Am Diet Assoc 87: 888-896.